ANALYZING THE VALUE OF INFORMATION SHARING AND INVENTORY REPLENISHMENT POLICIES ON SUPPLY CHAIN PERFORMANCE

by

Ahmed Shaban Shaban Khalifa

A Thesis Submitted to the
Faculty of Engineering at University of Rome "La Sapienza"
in Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in

INDUSTRIAL PRODUCTION ENGINEERING

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Under the Supervision of

Prof. Dr. Massimo Tronci

Professor of Industrial Plants,
Mechanical and Aerospace Engineering
Department, Faculty of Engineering,
University of Rome "La Sapienza"

Dr. Francesco Costantino

Assistant Professor,
Mechanical and Aerospace Engineering
Department, Faculty of Engineering,
University of Rome "La Sapienza"

Dr. Giulio Di Gravio

Assistant Professor,
Mechanical and Aerospace Engineering
Department, Faculty of Engineering,
University of Rome "La Sapienza"

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Bullwhip effect is defined as the distortion of demand information as one moves upstream in the supply chain, causing severe inefficiencies. Both the lack of coordination and the ordering policies have been regarded as the main causes of the bullwhip effect. Extensive research has quantified the value of information sharing of customer demand as a collaboration approach with considering that all supply chain partners can access to demand information in the real-time. However, limited research has been devoted to quantifying the value of limited collaboration or to develop easy-to-implement collaboration models and coordination mechanisms. Furthermore, the majority of the information sharing studies has focused on the quantification of the bullwhip effect without investigating the corresponding inventory performances. Several other researchers have been attempting to develop inventory control systems that can allow order smoothing in order to handle the bullwhip effect without the need for collaboration. However, the trade-off between the bullwhip effect and inventory stability has been obstacle to developing such policies. This thesis addresses the above issues by analyzing the value of information sharing and innovative replenishment policies on supply chain performances.

This thesis attempts to fill the first gap by investigating both ordering and inventory performances in a four-echelon supply chain employs the standard (R, S) policy, under different scenarios of information sharing level, through a simulation study. The results show evidence that the lack of information sharing increases both the bullwhip effect and the inventory variance while decreasing the average service level. Furthermore, the results show that the collaboration between the downstream echelons brings better benefits for the whole supply chain than the collaboration between the upstream echelons. The main and interaction effects of information sharing and other operational parameters in the supply chain have been quantified through a factorial design analysis. The statistical results confirm again that information sharing is the most significant factor to improve the supply chain stability. The poor forecasting, high safety stock levels and their interactions have a significant relative contribution to the instability across the chain, even when information is shared. The performance of the upstream echelons not only depends on their local operational parameters but also on the parameters considered by the downstream echelons and their interactions and thus coordination is essential is supply chains.

The second study of this thesis is devoted to develop easy-to-implement coordination mechanisms that allow information sharing in a decentralized way through the ordering process in multi-echelon supply chains. The first proposed approach “IS1” is a progressive information sharing approach

based on the ordering policy in which each echelon transmits his orders as two parts (instead of a single order quantity): customer demand and inventory adjustment. The second approach "IS2" is similar to "IS1" but more advanced and has a similar ordering structure to the generalized (R, S) policy in which replenishment order can be divided into demand forecast and inventory position adjustment. As the generalized (R, S) allows order smoothing, IS2 combines the power of both information sharing and order smoothing. Both IS1 and IS2 have been investigated in a four-echelon supply chain, through a simulation study. The results have shown that the proposed approaches are successful to mitigate the bullwhip effect whilst keeping acceptable inventory stability. Exhaustive comparison has also been conducted between IS2 and other coordination levels such as Traditional and Information Enriched Supply Chains (i.e., TSC & IESC) under various operational settings, through a factorial design. The IS2 has shown a superior performance (in terms of all performance measures) to TSC and a comparable performance to IESC. It is concluded that increasing the collaboration and order smoothing levels improves significantly the supply chain performances and decreases their sensitivity to operational parameters such as lead-time and forecasting parameter.

The final study presents an innovative inventory management system, named SPC, to be used in dynamic and complex environments like multi-echelon supply chains. The SPC system relies on two integrated control charts to monitor demand and inventory position for determining the time and quantity to order. It has a flexible structure where it can be turned into a generalized (R, S) by setting some parameters. The SPC policy has been evaluated and compared with the generalized (R, S) policy which allows order smoothing in single and multi-echelon supply chain models under various demand processes. The simulation results have shown that SPC outperforms (R, S) in terms of bullwhip effect and inventory stability. The SPC is successful to eliminate the bullwhip effect whilst achieving acceptable inventory performance under various testing conditions.